ARGRAVES

Methods of Reinforcing Concrete

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METHODS OF RE-INFORCING CONCRETE

BY

ARLOW J. ARGRAVES

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

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UNIVERSITY OF ILLINOIS

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C O L L E G E O F E N G I N E E R I N G

May 25, 1907.

This is to certify that the following thesis prepared under the immediate direction of Mr. Harry Gardner, Instructor in Civil Engineering, by

ARLOW J ARGRAVES

entitled DISCUSSION OF APPROVED METHODS OF REINFORCING CONCRETE

is accepted by me as fulfilling this part of the requirements for the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker

Head of Department of Civil Engineering

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INTRODUCTION

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Object of Thesis.-

On account of the comparative newness of the art of reinforcing concrete for building purposes, new ideas concerning the processes are constantly being presented, and experiments upon the finished product performed. The object of this thesis is to bring together, in so far as possible, information regarding the different methods of concrete reinforcement.

Reasons for Concrete Reinforcement.-

Concrete has a low tensile strength and consequently was first used to resist only compressive stresses in foundations, walls and so forth. By imbedding steel in concrete its

ability to resist shear and tension is greatly enhanced and thus the uses to which it may be put are greatly multiplied. Compressive stresses are generally successfully resisted by the concrete itself, though sometimes reinforcement is supplied to resist even those stresses.

Methods of Reinforcement.—

The methods of reinforcing concrete are almost innumerable. The most convenient classification however, seems to be as follows: Bar, Net, and Expanded Metal systems, each of which may be classified almost indefinitely.

I BAR SYSTEM.

The system of reinforcing concrete by means of bars is one of the most common. Various bars are used and suggest a variety of classifications, but

A - Plain round rod

nations of the rods. Among the
numerous systems of round bar
reinforcement - are :

1. The Cummings System.

In this system round bars
of different [illegible]
their ends [illegible]
[illegible] cummings,
[illegible] others, on having a
[illegible] chair, for the rods, a
[illegible] 1. A chair is

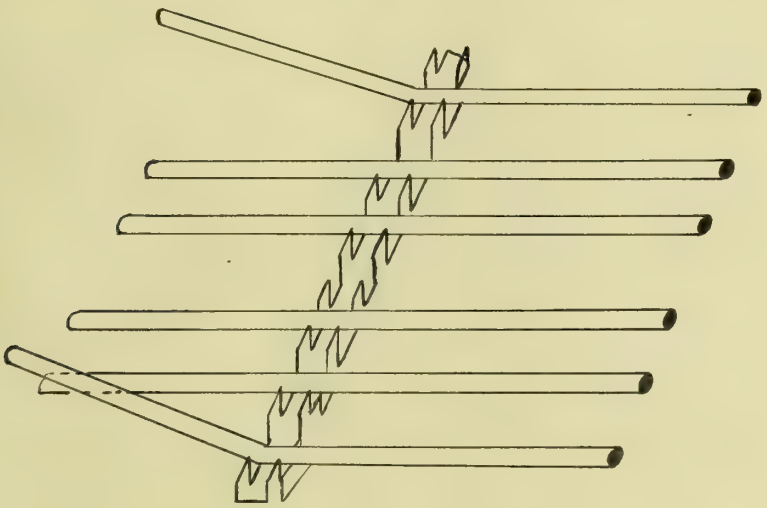


Fig. 1 - Cummings Chair.

stamped from strips of steel

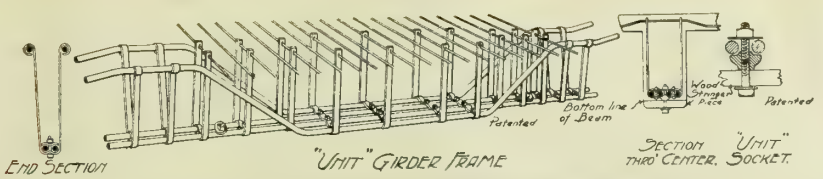
band steel, having projections which are bent up to form the heel. Reinforcement for compression is made by using "Cummings self-locking steel staples and rivets," the hoops being made of flat steel bent in a circle with the ends riveted together and one end bent outwardly at right angles to the hoops. The spring cushions consist of light steel staples provided with small holes for studs to attach the hoops and gradually lessening in the cushions.

The advantages claimed for this system are: 1. The exact distribution of the steel for tensile stresses, the rods being of calculated size. 2. No unnecessary steel staples are placed, and can be removed when 3. The shapes are comparatively simple and so can be had at minimum cost. 4. The band is of best

[illegible]

A good example of the Cummings system is the [illegible] Manufacturing Company's [illegible] the [illegible] Pennsylvania. The [illegible] is 60 feet [illegible] and height 57 feet [illegible] reinforced by columns [illegible] [illegible] centers to [illegible] being 20 inches in diameter [illegible] [illegible] steel [illegible], the [illegible] [illegible] [illegible]

concrete is not obtained by the use of a single trussed nor twisted bar but is a combination of round bars built in the form of "cages" or "skeletons" about which the concrete is packed. The invention of the system culminated from the fact that most reinforced concrete [illegible] labor and placing the reinforcement as a unit eliminates to a great extent the personal equations of the workmen. The rods in this system are fastened together as shown in figure 2.



"UNIT" GIRDER FRAME (PATENTED)

Fig. 2

The following is a [illegible] "Fire, Load, and Water Test," on a "Unit" Concrete Steel Frame Co. floor, conducted

June 16, 1905 at Columbia University.
[illegible] Deflections are in sixteenths of an inch [illegible] The minus sign indicate rising tendencies [illegible] tendencies.

Time	West Beam			Middle Beam			East Beam		
	Deflection.			Deflection.			Deflection.		
	1	2	3	1	2	3	1	2	3
10:45	0	0	0	0	0	0	0	0	0
11:00	−1	−1	1	−2	0	−1	1	−1	0
11:15	2	2	3	4	5	1	3	6	5
11:30	4	3	5	5	4	−1	4	5	5
11:45	5	4	5	5	11		6	9	6
12:00	8	10	6	8	11	3	8	12	7
12:15	8	8	7	9	7	9	5	13	8
12:30	9	10	8	9	10	10	9	12	9
12:45	9	8	10	9	8	9	6	9	8
1:00	11	5	11	11	9	8	11	7	11
1:15	7	4	12	12	7	8	8	6	10
1:30	7	4	12	10	8	12	9	5	12
1:45	12	12	13	13	7	13	8	5	8
2:00	14	0	14	7	9	13	9	8	9
2:15	8	3	14	13	9	12	6	11	12
2:30	15	9	15	13	13	13	10	6	13
2:45	16	9	16	12	13	12	15	8	14
				Fire out. Cooled down to normal					
9:00	1	17	−8	0	24	0	−1	10	6
				Load of 650 pounds per square foot.					
3:00	3	12	1	8	18	4	3	12	5

Corrected Total Deflections.

for middle of beam. taking into consideration the rise of ends of beams.

June 16 2:45	W. B	M. F.	E. F.
	$1\frac{9}{16}$"	$1\frac{27}{32}$"	$1\frac{9}{16}$"
June 17 9:00	$1\frac{5}{8}$"	$1\frac{1}{2}$"	$1\frac{9}{16}$"
3:30	$1\frac{7}{8}$"	2"	$1\frac{13}{16}$"

Note: The results were obtained as follows: For all beam deflections when the ends rise and the middle falls, the deflections of the middle were added to the mean of the rises of the ends. When both middle and ends fall the sum of the mean deflections of the two ends from the deflection of the middle.

The following advantages are claimed for the "Unit" system: 1. Economy of time in placing since the beam is delivered in a unit. 2. ease with which it can be installed by the ordinary 3. [illegible]

[illegible] 4. When the [illegible]

[illegible] bolts

[illegible] "Kahn" [illegible] Bell Franel Co. of [illegible] [illegible] information may be obtained.

3. Hennibique System

[illegible] Hennibique [illegible]

[illegible] French engineer [illegible] the most successful concrete-[illegible]

[illegible] Principally [illegible] [illegible] [illegible]

4 Coignet system

the nearest supports, and to secondary bars of smaller cross-

[illegible] tests, [illegible]
[illegible] with [illegible] of the [illegible]
[illegible] square [illegible] sections.

To give an idea of the efficiency of this system, the results of tests made at the testing establishment of the British Fire-Prevention Committee, these tests were made upon a simply-supported concrete floor panel 10 feet long by 10 feet wide, reinforced with concrete beams, 12 in. deep, consisting of 3 top and 3 bottom bars, 5 feet long by 7 feet; [illegible] reading both ways over the floor. Each intermediate beam had 2 steel rods, 6 feet long by ½ inches in diameter in the lower part, and 2 - 9/16 inch rods in the horizontal plane near the bottom, and two similar rods near the top. The reinforcement was connected up by means of stirrups and tied. The floor was 6 inches thick and the depth of the beams [illegible]

the [illegible] of [illegible]
concrete [illegible] work, the floor being
laid [illegible] to [illegible] after [illegible]
load of 250 pounds per square
foot [illegible] placed, and the temp-
erature raised to 1,000°-1,100°F. Heating
began [illegible] minutes after
the gas was lighted, the total
being 5.6 inches in 23 hours. Water
was then applied and the concrete
on the [illegible] was [illegible]
causing the [illegible] to [illegible].
When the load was removed cracks
showed in the direction of the
beams and the movement of one
5/8" inch. In this test, [illegible]
per cent was saved through the floor.

Bibliography:

The original [illegible]
"Concrete System" — Eng. Record & Cliff Hous.
Sept. 29, 1906; "Fire Tests with Flues" —
Engineering, July 3, 1906.

5. Siegwart System.

This is a ferro-concrete construction system and was developed at Lucerne. It differs from most others in that the beams are made at the factory and not on the site. Concrete (steel) pieces are transported to the site and the reinforcing rods bent in the top and bottom.

Tests were made upon a Siegwart floor built of beams 9.84 inches wide and 9.66 inches deep, side walls 1.18 inches thick, bottom walls 1.00 inches thick and the cover 1.57 inches thick, the reinforcing rods being .275 inches in diameter. The span was 13.45 feet C-C. The floor being designed for 81.9 pounds per square foot. It was loaded 2½ times the load designed for, the deflection being .0397 inches and the per-

cent per cu. ft. will suffice. The cost is no cracks.

The advantages claimed for the Hennebique system are: 1. Lightness because of ribbing, etc.; 2. They are poor conductors of sound thus being quite a factor to be considered in manufacturing buildings. 3. Economy of time on account of not being compelled to wait for concrete to harden. 4. Ease of transportation.

These beams are not yet very widely used. A description is given in the Engr. Jan 29, 1904

6. Cottancin System.

The other system in much used is the Cottancin system. [illegible] much engineers believe the chief advantage of the Cottancin system is the combination of steel rods and a mesh system [illegible]

openings varying with the load to be placed upon the structure. There are two special forms of the Cottancin reinforcement. Figure 3 shows what is known as the "lattice-pattern reinforcing skeleton", which consists of ½" round rods bent at certain distances, then [illegible] at right angles. Figure 4 shows

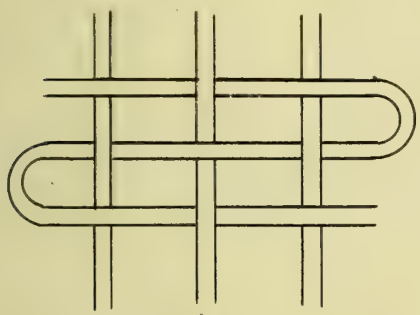


Fig. 3

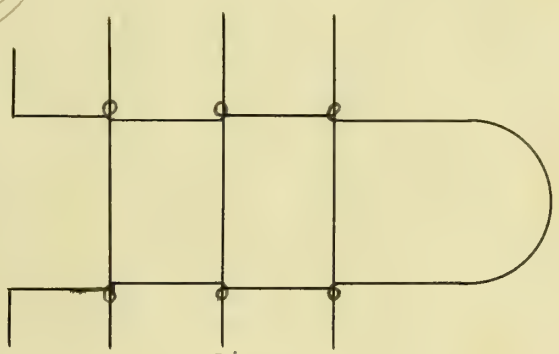


Fig 4.

the "continuous skeleton with the woven spiral". In each case [illegible] the concrete can be firmly [illegible] into the interstices, on account of the ease with which the rods can be bent the Cottancin can be used in artistic structure. It is used however more largely in foundation several cases of which are described in "Concrete-Steel" by [illegible] Wolverton. This system has been [illegible]

used in France, but its use has not increased as rapidly as some others in the United States.

Bibliography:

"Practical Applications of Reinforced Concrete," Eng. Mag. Jan. 1901.

B. Bars of Rectangular Cross-Section.

This division of the bar system includes a considerable variety of shapes. Among those most commonly known are:

1 Johnson Corrugated Bar.

The Johnson corrugated bar is square with frequent corrugations surrounding it, as shown in figure 5. High carbon steel is used

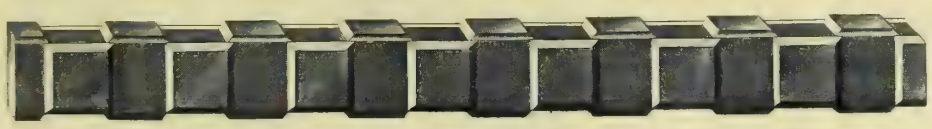


Fig. 5. Johnson Bar.

55000 pounds elastic limit and 100,000 pounds per square inch tensile

strength. The chief reason for the introduction of steel for the reinforcing concrete was the lack of bond between smooth bars and concrete. To quote Professor Talbot from his Data of concrete beams, bulletin number 14, page 25: "The value of bond in resistance with depend upon the smoothness of the bar, the uniformity of its diameter, the relative strength of the concrete, and the shrinkage grip developed in setting." On page 41 of the same bulletin in reference to tests made on beams with smooth bars Professor Talbot says: "Owing to the extremely smooth surface and comparatively small cross-section of these bars, these beams did not develop as much strength as those reinforced with mild steel, the tensile strength being only half the elastic limit of the material. The bars pulled out while still in the elastic limit, followed by partial and complete cracks."

... the advantages claimed for the
[illegible] bar are 1. [illegible]
[illegible] [illegible] [illegible]
[illegible] be [illegible] for [illegible]
because the elastic limit is very
high. Consequently [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
the concrete covered [illegible] to take
tensile [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible] [illegible]
[illegible]

* Concrete "split" Mixture = 1:2:4

† Concrete "split" Mixture = 1:3:6

‡ Concrete "split" Mixture = 1:4:8

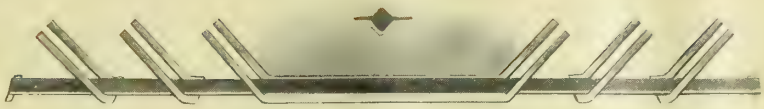
[illegible] the [illegible] of the [illegible] of the Johnson [illegible] on the Hydraulic Canal [illegible] 40 feet long, 6 feet deep on the [illegible] land, being 17 feet high, 40 feet wide at the base and 5 feet wide at the top. It is entirely reinforced with 10-foot Johnson [illegible] 1/4 inches square. The [illegible] are based on [illegible] piling foundations 15 feet long, the piles being 12 inches at the [illegible] and 17 inches at the base. [illegible] graphy:

"The Johnson Bar Reinforcing System," 8,'06; "Catalogue" Expanded Metal and Corrugated Bar Co., St Louis, Mo.

2. Kahn Trussed Bar.

The Kahn trussed bar is a horizontal, flanged bar with the flanges [illegible] at intervals. There are two general types of the Kahn bar; The Regular type is shown in figure 6, and the alternating type

7.



Kahn Trussed Bar, Regular Type.

Fig. 6

Fig. 7.

The distinguishing feature of the Kahn bar is the "provision against shear, or tension and shear together. A beam whe[illegible] reduced [illegible] a tendency [illegible] along a [illegible] with the vertical. The [illegible] inclined to this principle [illegible], the [illegible] The tensile stresses and the shearing stresses [illegible] stresses).

Some of the advantages of the Kahn bar [illegible]: 1. Simplicity of [illegible] the same bar resisting tension, compression, and shear, 2. Simplicity and rapidity of construction

3. Good bond, the metal being distributed pretty uniformly.

Some of the disadvantages are: 1. Limited skeleton would be very large of section, 2. Inconvenience in shifting an arrangement of forms in floors, 3. Difficulty of keeping line concrete.

Among the many examples of reinforced concrete in which the Ransome system was used is the Metropolitan-Kleinheim Hotel, at Atlantic City, N. J. The Kahn bar was used in all the columns, girders and floors. The main body of this building is nine stories high, while surrounding the dome there are fifteen stories. The length is 500 feet and the width varies from 150 feet to 250 feet. The main structure was erected in less than six months, while if other materials had been used it is estimated that it would take a year at least to complete. In addition this building is imposing, and the details of the interior, such as

cantilever balconies, turrets, domes,
[illegible] etc. [illegible]
[illegible] [illegible]
tectural effect.

Bibliography.

"Cement and Concrete"
[illegible]; Ransome
[illegible] Concrete
Steel Co., Detroit, Michigan.

3. Plain Square Bar.

The plain square bar is not used nearly as much as formerly. The chief objection to it is the sharp corners which tend to crack the concrete when a load is applied.

C. Irregular Cross-Section

All bars that are not included in plain round rods and bars of rectangular cross-section, we will classify as bars of "Irregular Cross-Section." This system of reinforcement includes an almost infinite number of shapes some of which are [illegible]
similar but are [illegible]

to suit the [illegible] different [illegible]. Each [illegible] has certain [illegible] advantages claimed for it. Among the principal [illegible] of reinforced concrete construction are:

1 Ransome Bar.

The Ransome bar is one of the first steel rods shaped so as to give a mechanical bond with concrete that was invented by W. Ernest L. Ransome who was the first man to design and erect a reinforced concrete bridge in America. The shape is obtained by twisting [illegible] uniformly square bar with square cross section the primary object of twisting being to give a continuous screw thread to the bar and to effect only a slight reduction in the area. The twisting also increases the elasticity that can be imparted to the metal since tests show that if properly the elastic limit of the steel can not be estimated higher than fifty per cent, and it is usual to [illegible] for

the quality of the steel since any irregularities will show when the bar is twisted.

Following are the results of the Kinsome bar with plain bars:

Size "□	E.L. #/□"		Ult. Str. #/□"		Price per 100#	
	Plain	Twisted	Plain	Twisted	Plain	Twisted
1/4	46,170	6[illegible],350	51,800	36,700		
1/2		60[illegible]0		86,[illegible]50	$1,30	$[illegible].10
3/4	34,840	56,1[illegible]0	59,[illegible]00	85,240	1.73	2.53
7/8	39,700	56,150	62,100	84,730	1.50	1.80
1	-	55,760		84,[illegible]75		
1 1/4		53,450		83,13[illegible]		

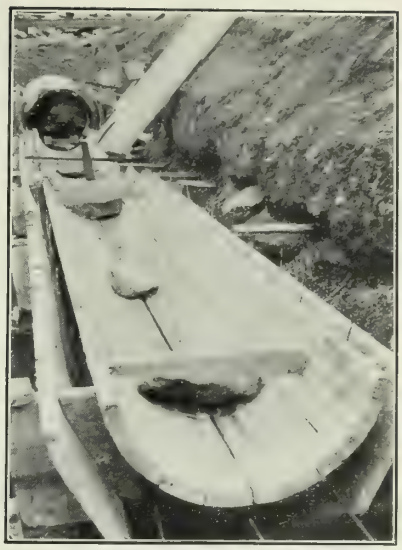
For a bar smaller than 3/4 inch $1.80 is added to the price of plain rods etc. The prices given are relative and not exact and the above Elastic limits and ultimate strengths are taken from the record of tests made at Columbia University by Professor Wm. A. Hanson.

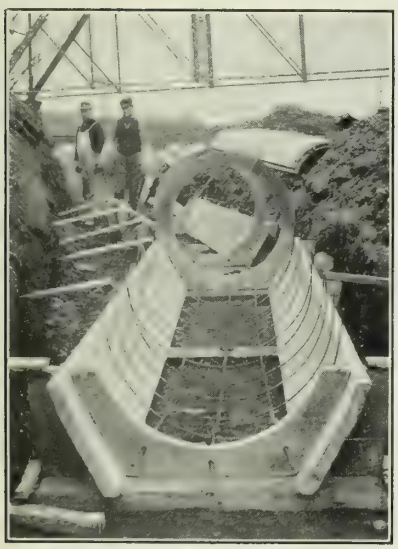
The Kinsome bar is excellent in case where any other bar is to

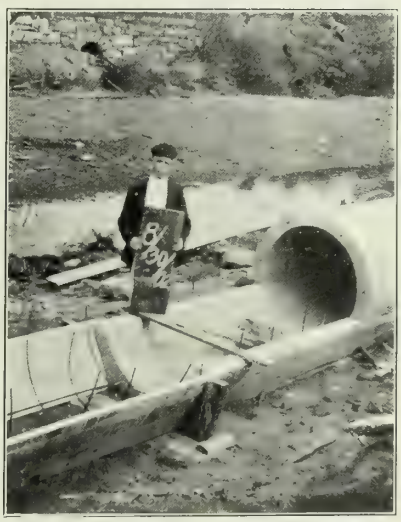
cised. It is used to give ...
...xtent in chimney construction,
...an example of which is the
smoke stack of the Pacific Electric Co.
Los Angeles, California. It is 180 ft.
high, the base being built 15
feet in the ground and the
inner diameter being 11 feet. It
is slight 1 51 at the stack assumes
a circular form. Here the form
Ransome construction is to be seen
on the ...ing tests of Feb 1903.
New Jersey. The tests are reported
with 2 used Ransome ... the
longitudinal bracing. ... the
largest reinforced concrete buildings
in this country are the Ideal Sta...
...mpany factory, Brooklyn. It comp...
...s a four-storied ... consists
of eight stacks and a basement,
with a total floor area of 170,000
square feet.

Following are some cuts showing the
method of using the Ransome bar and
also some tests by the ... construction
Company.

Bibliography:

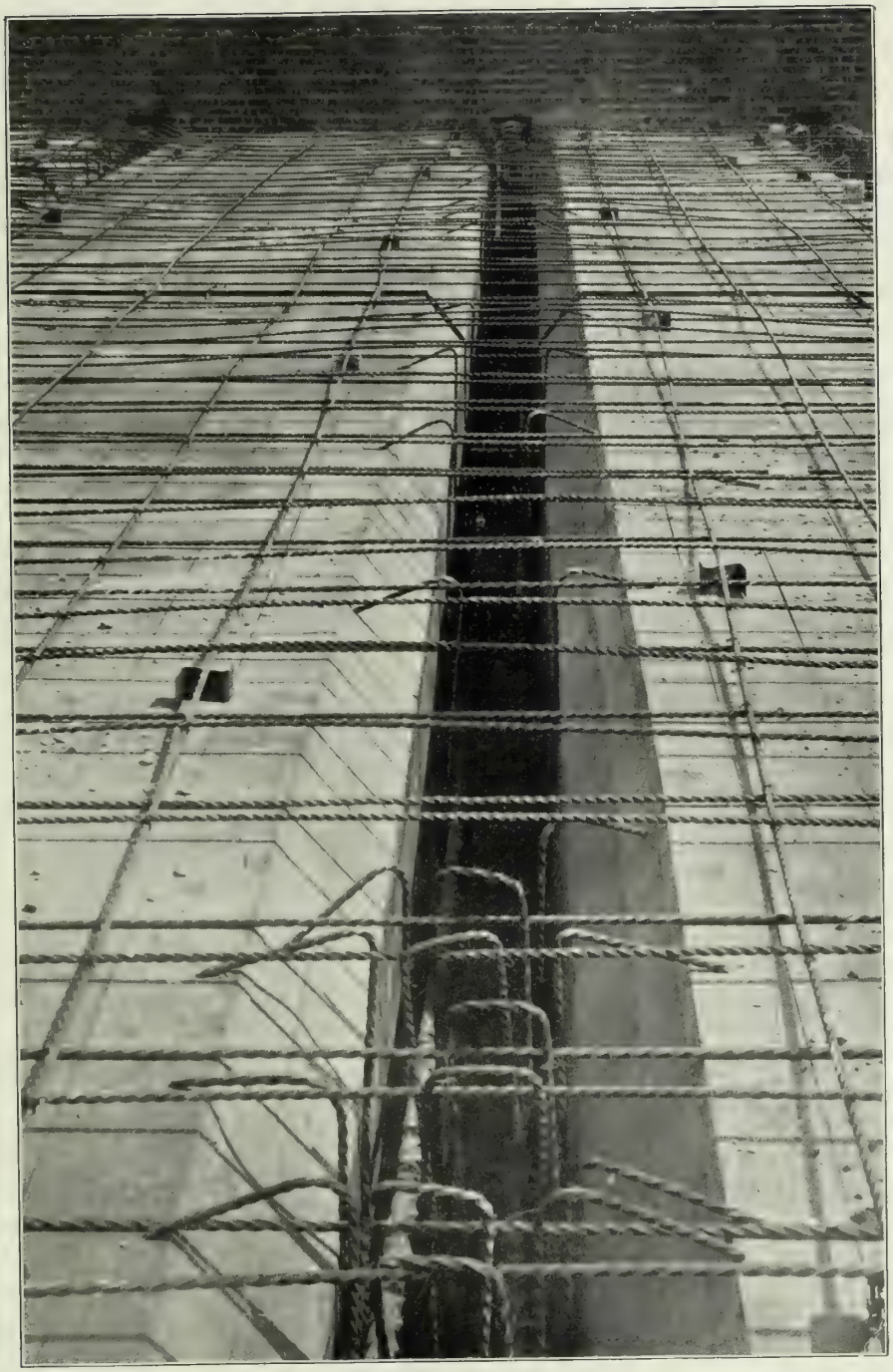






Concrete sewer, Ransome System. Built by Westinghouse, Church, Kerr & Co., at Scranton, Pa.
Designed by Turner Construction Co.

The South Pub Press, 195 Fulton St., N. Y.



Wm. Higginson, Architect. Erected Summer, 1905.

Brooklyn Riding and Driving Club Garage. Showing wood centering and twisted steel bars for 50-foot floor span.

"Forms of Concrete Reinforcement" Iron Age Jan. 4, '06; "Reinforcement" Turner Construction Co. 11 Broadway, N.Y.; "Handbook" Wilson B. Keough Co., Chicago Ill.; Eng. News, Mch 1, 1902; Eng. News, Apr. 2, 1903; Eng. News Apr. 9, 1903; "Concrete Metal Construction" Jour. of Eng. Soc., Feb. 1901.

2. The Melan System.

The Melan system of concrete reinforcement consists in embedding I-beams in concrete without any close-set connections the beams being arranged parallel. The beams used in such construction are from 6" to 24" high at a cost of 1¢ per lb. The Melan system seems to meet with special favor among the American engineers who have performed many tests upon it. The results of some of these tests made by the Austrian Government concerning the Melan system with fibre and the with a simple concrete and with reinforced concrete will [illegible]

Results of Austrian Tests

Material	Span ft.	Rise in	Thk's of Crown in.	Amt of Steel #/□'	Breaking load - #
Brick-in Cement	13⅓	15¾	6		1.5
Concrete	"	"	4		731.3
Monier	"	"	⅜	3	239.1
Melan	"	11.0	⅛	1.7	360.0
Wayss & Koch	16.1	2.00	7.0	1.5	1010.0

At Stubbing, Mass., there is a Melan arch of 100 foot span 10 feet rise, 7 inches thickness at the crown and 30 inches at the haunches; 7 in. X 15 lb. I-beams were used, spaced 28 inches apart and the concrete was a 1:2:4 mixture with Portland cement. The foundation is partly on stone and partly on gravel and the arch is symmetrical in respect to the different depths of the banks. The cost of the work was $1,475.

The principal advantages of the Melan construction are: 1. Economy of material. 2. Great strength. For [illegible] of both see the above.

Bibliography: —

1. "The Melan System" — [illegible]

Apr. 13, 1894, "The Hennebique and Melan Systems of Reinforced Concrete Construction" - Eng. News Apr. 12, 1894; "Melan Arch Bridge" - Eng. News, Oct. 3, 1895; "Notes on Monier and Melan Arches" - Eng. Mag. Oct. 10, 1895.

3. Columbian System.

The Columbian system is under the control of the Columbian Fireproofing Company of Pittsburg Pa. It is used principally in fireproof floor construction, the characteristic feature being the double cross shaped bar as shown in (a), figure 8. The Columbian floors are made in two styles; "long

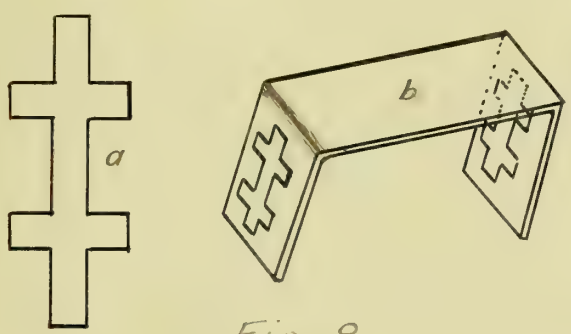


Fig. 8.

span" and "short span". In each case I-beams are used and the bars are placed at right angles to them, being spaced about 2-4 inches apart. In the "long span"

construction the bars are hung to the I-beams by means of stirrups. The sketch (b) Fig. 8 represents one of these stirrups. Angles are sometimes used, while in the "short span" construction stirrups are always used.

The following table gives the safe carrying capacity of Columbian floors as compiled from actual tests.

Long Spans					Short Spans.				
Distance between Supports	Uniform Load. Bars 24" C-C.				Distance between Supports	Uniform Load Bars 24" C-C.			
	6" Bars	5" Bars	4 1/4" Bars	1" 2 Bars		2 1/2" Bars	2" Bars	1" Bars	
Ft.	lbs.	lbs.	lbs	lbs.	Ft.	lbs.	lbs.	lbs	
12	412	362	312	275	5	400	340	290	
13	346	306	265	235	6	275	240	200	
14	296	260	230	200	7	200	178	140	
15	256	226	200	175	8	150	135	110	
16	225	200	175		9	120	100	70	
17	200	175	125		10	100	70		
18	177	150			11	80			
19	140	100							
20	100	80							
Concrete Thickness	11/2"	6 1/2"	5 3/4"	5"		4"	3 1/4"	3"	

Letter w[illegible] note that [illegible] 3. hour's fixation [illegible] floor in Boston [illegible]

[illegible]

[illegible]

[illegible]

"Reinforced Concrete"
Buel & Hill; "Kidder's Handbook", and
Eng. News, Nov. 21, 1901.

4. Wuensch System.

[illegible]

The Wuensch system is used
chiefly for arch bridges and culverts
[illegible]
[illegible]
[illegible]

crown, and at the abutment are connected by vertical members, these verticals being connected at their base by channels running transversly to the [illegible].

This method is said to be cheap, costing [illegible] and is very efficient in strength as is shown by the results of tests made on a 16.6 foot arch by Hungarian engineers. The arch was designed to carry 84 pounds per square foot.

Total Load	Load lbs. per sq. ft.	Deflection Quarter Point	Deflection Mid Point	Deflection Quarter Point
[illegible]	93			
[illegible]	105		.04	.04
[illegible]	[illegible]		.16	.14 *
[illegible]	360	[illegible]	[illegible]	[illegible] †
[illegible]	410		.59	[illegible] ‡
[illegible]	465	.15	.64	[illegible]
[illegible]	1010		.71	

* Fine Crack began to show.

† [illegible]

‡ Cracks open to .08 inch

8 stacks increased slowly to break-down.

Up to 1894 there were only six chimneys of this type built in Hungary by the Monier system, the [illegible] being from 3 feet to 55 feet. More than many have been built, among them one at Neuhausen which consists of six flues of 36 feet each with a size of 3.7 feet and a thickness at the crown of 1.3 inches and at the [illegible] line of 54.3 inches.

Bibliography.

"Cement and Concrete" – Sabin;
"Concrete and Iron Structures" – [illegible] Jan. 13, '94;
"[illegible] Reinforced Concrete Systems" – [illegible]

5. Weber System

The Weber system is used in chimneys only and is patented by The Weber Steel-Concrete Chimney Company, 924-934 [illegible] Building, Chicago. The first [illegible] Weber chimney was erected [illegible] and dated Dec. 29, 1903.

The foundation of the Chimney is made of 1:3:5 concrete reinforced by four layers of steel of small size. The thickness between the layers varying with the height of the chimney and the carrying capacity of the soil. The lower layer is placed horizontally while the upper are placed parallel with the sides of the foundation.

Vertical rods, forming the reinforcement for the shaft, extend from into the foundation and are bent in ends to secure good anchorage.

The chimney shaft consists of two parts; a four brick wall and an upper single shell, these being united at the offset which is at about one third of the height, but varying somewhat with the nature and heat of the chimney gases, draught of chimney, and the weight of the more strong. The thickness of the inner part of the shell wall is generally four inches

and the outer shell six or seven inches, while that of the single shell is from four to five inches. There is a dead air space between the two parts of the double shell allowing the inner part to expand and giving it protection from the weather and at the same time furnishing protection to the outer part from heat. The expansion joint is covered where the two shells unite. No panel or stone is used over ground, the mixture being Portland cement and sand. The steel used is from 16 to 30 feet long and tapers not less than 24 inches, the joinings being very irregular to prevent any unusual weakness, and the circumferential spacing is 18 inches. In vertical cases "all single" or "all double" wall chimneys are built. The work of erection is done from the interior, no external scaffolding being needed.

The advantages of the "Hoyer" chimney claimed by its makers are as follows: 1. The "Hoyer" chimney

is smooth & without any joint or interruptions. The air has no disintegrating effect on a steel chimney. 2. It is air-tight, of uniform inside diameter and almost perfectly smooth giving higher working capacity than others. 3. It can be erected more rapidly than brick or steel and the material & construction are easily obtainable in any locality. 4. It occupies less space than a steel or brick chimney since the base is not nearly so large. 5. It is lighter than either brick or steel" In different localities it is chiefly a question of cost. 6" Its outside appearance is better than brick or steel in general use, chiefly on account of its shape, color &c." In this way the best working chimneys are found. First taken in the editorial toward the top and the Weber Chimney stock not.

The highest chimney of this type is one built for Colonel Hearst Mining and Smelting Company, Butte, Montana: its height being 350 feet and its inside diameter 18½ feet.

WEBER STEEL-CONCRETE CHIMNEY COMPANY.

CHIMNEY

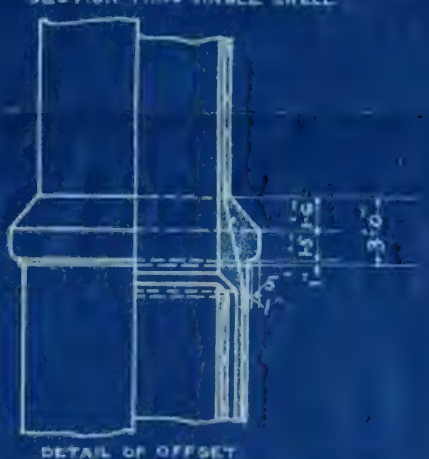
175 FT. HIGH AND 8 FT. 0 INS. DIAM.

FOR

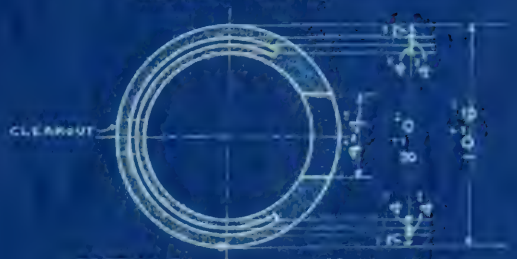
C.R. MAKEPEACE AND CO.
NEW BEDFORD, MASS.

DETAIL OF HEAD

SECTION THRU SINGLE SHELL



DETAIL OF OFFSET



SECTION THRU SMOKE OPENING

BASE

FOUNDATION AND VERTICAL BARS ARE $1\frac{1}{8}$" A $1\frac{1}{4}$" x $\frac{3}{16}$" T.S.
RINGS ARE $\frac{5}{8}$" ROUND BARS SPACED 18"

ENGINEERING DEPARTMENT.

CHICAGO, NOV. 6, 1906. J.W.

Changed 11/8/06

DO NOT SCALE THIS BLUE PRINT.

[illegible] adjacent [illegible] [illegible]
[illegible] details [illegible] [illegible]
Bibliography.

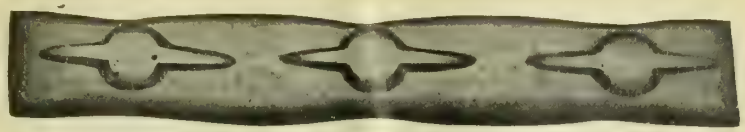
"[illegible] Chicago" [illegible]
Steel-Concrete Co., Chicago, [illegible] Architects
[illegible] Pocket-Book" [illegible].

6. Thacher Bar System.

This system, like all the [illegible]
systems, is characterized by the
use of [illegible] for which [illegible]
[illegible].

The Thacher bar is a [illegible]
steel bar originally rolled from the
ordinary **I** beam. This bar is
called the "Thacher Steel Engineering Co."
bolts. These at special rolling
mills. The sections are [illegible]
[illegible] [illegible] [illegible] [illegible]
in section such changes in product
[illegible] securing all [illegible] requirements,
giving it the appearance as shown
in figure 9. Bars are obtained from
1/4 inch to 2 inches in diameter. A
table showing ultimate strength, weight

for round bars is given in Kidder's "Architect & Builder's Pocket-Book" page 1, which table will be given here.



THACHER PATENT BARS

Fig. 9

Diameter inches	Area sq. in.	Weight lbs per lin. ft.	Ultimate Str. Ind. Steel
1/4	0.047	0.16	5,000
1/2	0.13	0.61	11,500
3/4	0.11	1.39	16,700
1	0.11	2.47	25,400
1 1/4	1.10	3 1/4	10,400
1 1/2	1.56	5.50	39,800
1 3/4	2.08	1.01	53,100
2	2.63	9.01	169 600

The advantages of the Thacher

1. There being no sharp corners, it does not have a tendency to crack the concrete. 2. There is good bond due to the irregular surface of bar. 3. It can be used for any construction that any deformed bar of

ture is used for, being easily cut to various shapes. 4. It is as easily shaped as any other.

The reinforcement of the arches for weathering is found in a concrete bridge at Grinnell Colorado and which is described in the Engineering Record for February 10, 1906. There are 3 ribs for each span, the rise being 7 feet and the clear width between parapets 64 feet including 2 - 4 foot railway and 2 - 6 foot sidewalks. The arches were designed for a live load of 125 pounds per sq. ft. The concrete being 1 to 2 to 4 mix and the haunches 3 feet thick. Sixty-four pairs of 1⅛ inch bars were used longitudinally and twelve pairs of ¾ inch bars transversely.

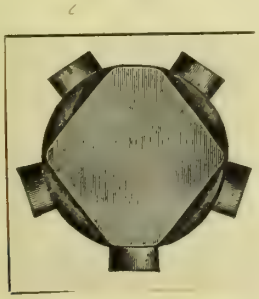
Bibliography.

"Architects and Builders Pocket Book" Kidder;
"Reinforced Concrete" Taylor and Thompson.

7. Lug Bar

The Lug bar is a new shape [illegible] by the "Metal Fireproofing Company" of [illegible]. It is practically the same as the Thacher bar with the exception of the lugs which are intended to still further increase the bond to the concrete. The lug bar is also twisted cold to increase the elastic limit and as a test upon the quality of steel used. "All bars must bend cold, 180° to a diameter equal to the thickness of the bar without signs of fracture on the outside of bent portion". They may in size from $\frac{1}{4}$ inch bars to $1\frac{1}{2}$ inch bars, variations being by $\frac{1}{8}$ inch.

Further detailed information as to tests etc. can be had of the manufacturers. A cut of this bar is given in figure 10.



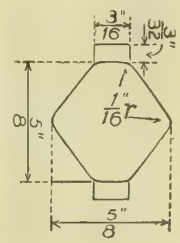


Fig. 10 - Lug Bar

MONIER SYSTEM

The Monier system of reinforcing concrete is the oldest system known to exist, its first application being the construction of a tub or vat by Monier and exhibited by him in 1855 at the Paris exposition. The skeleton of the boat was formed of a wire netting imbedded in concrete. It is still used in the city park of Miraval in central France. Francois Monier claimed to have been the discoverer of the advantages of combinations of steel and concrete and was issued patents covering all uses of steel and concrete. Other patents were also issued but were invalidated when it was proven that he was not the first inventor of concrete steel. The invalidation of Monier's patents enabled others to present their ideas along these lines and consequently many methods of reinforcing followed.

1 Monier System.

The Monier system of concrete reinforcement was one of the earliest if not the first system in which the net reinforcement was widely used. It was invented by Mon Monier of Paris and consists of small steel rods placed at right angles to each other and wired at the points of intersection. No attempt is made to increase the adhesion of the steel and concrete by bending the rods. The system is designed to resist both compressive and tensile stresses. On account of the shape of the cross section of the rods used the Monier system would properly be classified as a bar system but since the general form of the reinforcement is net it will be easy to arrange it under the net system.

The Monier system as applied to arches consists of the use of only one size of rod, though two sizes are often used, the

[illegible]

[illegible] "[illegible]" [illegible]

[illegible]

[illegible]

[

deformed more but the concrete is given more reinforcement and the work of placing is greater since the kinds of reinforcement are not mechanically connected as in some systems.

5. "Cracking".

6. "Adaptability to different shapes".

5 & 6 are obviously true.

The example of Monier construction is the Wayss & Freytag Concrete storage tanks which are described in the Engineering News for December 11, 1902. The eight inch floor slabs were reinforced with #10 wire in the base, and "corrugated" bars with 1/4 inch projections were used in the walls. Another example of Monier construction is the bridging ridge over Hernad at Miskolcz, Hungary. The span is 50 feet and the rise is 7.5 feet.

Bibliography.

"Monier Construction" Journ. of the A. of E. June, 1900; "Latest Method by Monier System" - Eng. News, Vol. 35, 1896; "Description of Monier Pipes" - Eng. News, Vol. 1, 1893; "Concrete and Iron Pipes" - R. R. Gaz. 4/3/94

2. Roebling system.

The Roebling system is noted chiefly for its use in floors, though it is also used in column ceilings and girders. As employed for floors in steel buildings it consists of arches of concrete reinforced by wire netting. The arches spring from the steel beams and rest on the lower flanges, the rise in the arches being about three inches less than the depth of the supporting I beams. On these arches flat round concrete is deposited, making a plane monolithic construction admirably adapted for a finished floor. The ceiling consists of a system of supporting rods extended to the lower flanges of the I beams by plate clamps. Beneath the supporting rods and securely wired to them is the flooring. Standard lathing is a wire mesh, the wire being

[illegible] at right angles. One-fourth inch [illegible] are woven into the wire lathing, crossing the [illegible] at right angles with the [illegible] method is clearly shown by figure 11.

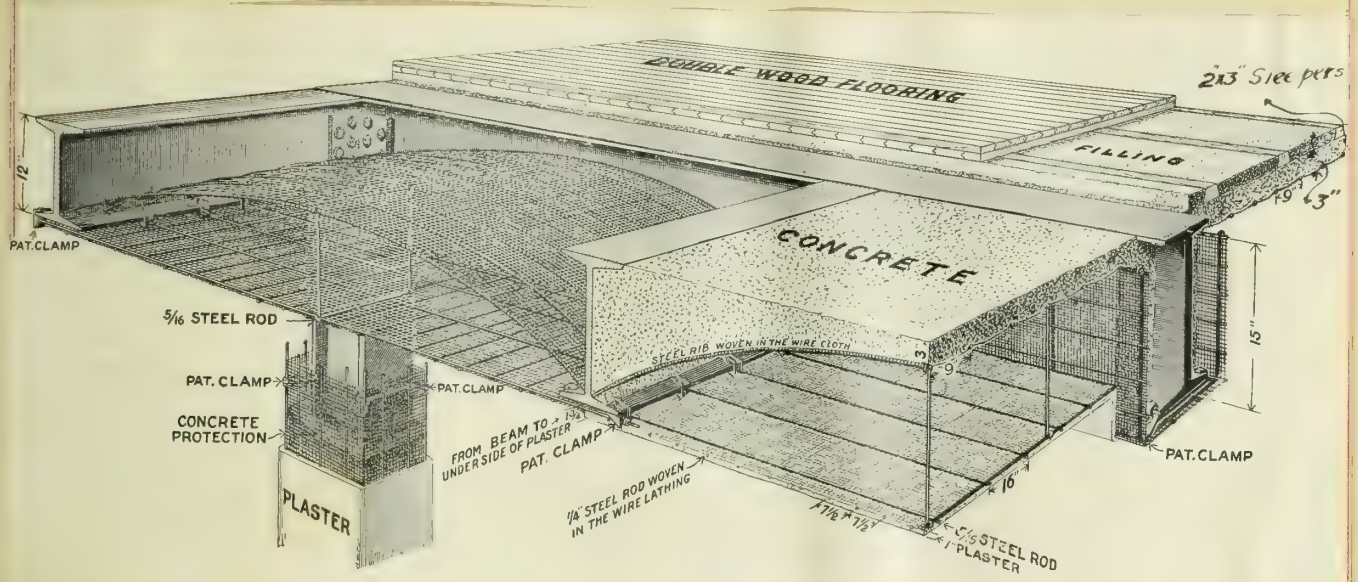


Fig. 11- Roebling Construction.

Some of the advantages of the Roebling system are:

1. "Saving in steel and economy in construction". It is said that the cost of this construction is 10-20 percent [illegible] that the Boston Building Department has approved.
2. Greater strength and stiffness on account of the homogeneous structure"

[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]
[illegible] [illegible] [illegible] [illegible]

...ey by the fire and water".

... The Roebling system of reinforced concrete construction was used, is the [illegible] of Roebling, New York. It is the largest [illegible] in the world and has a floor space of 554,600 square feet in which the Roebling system was used throughout.

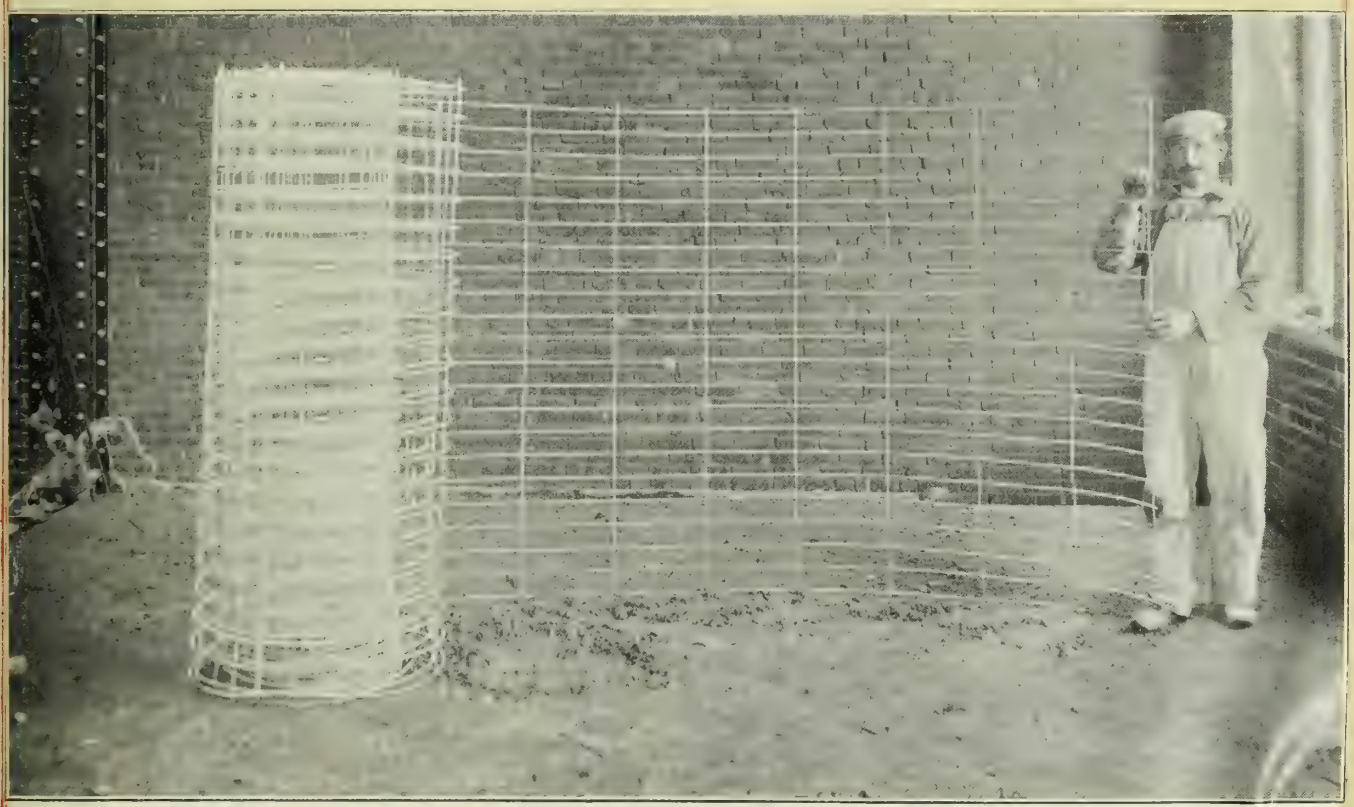
Bibliography:

"The Roebling System for Iron and Steel" - Eng. News, July 13, 1905; "Concrete Metal Construction" - J. of Eng. & Arch. 1901; "Forms of Concrete Reinforcement" - Eng. Rec. Jan. 11, 1906; "The Roebling System of Fire Proof Construction" - Roebling Construction Co. 121 Liberty St., N. Y. City.

3. Clinton Wire Cloth System.

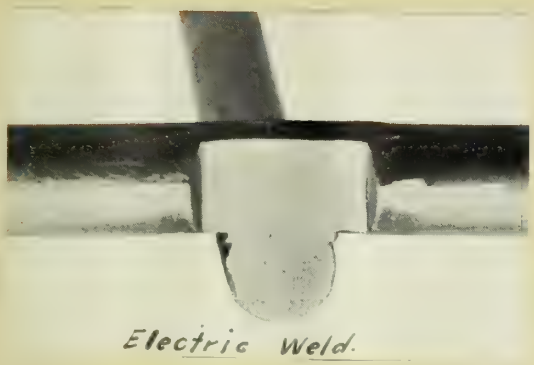
This system is the one used by the Clinton Wire Cloth Company of Clinton, Mass. who are the inventors and sole manufacturers of the metal used. The wire cloth used

This system is the "Clinton Electrically Welded Metal Fabric." It is extensively used in the United States as a reinforcing material on nearly all kinds of reinforced concrete construction. Figure 12 is a cut of the Clinton Fabric" and Figure 13 is a cut showing the weld between the longitudinal and transverse wires.



A ROLL OF CLINTON ELECTRICALLY WELDED FABRIC.

Fig 12



Electric Weld.

Fig 13.

Notice that it is impossible to detect the junction of the wires; in other words, there is a perfect weld and it is a notable fact that tests made upon the fabric have proven that the wire invariably breaks at some other place than at the joint. Fabric made of No 6 to No 10 gauge, (B. & M. gauges), drawn steel wire is used up to lengths of 300 feet. The wire can be used either plain or galvanized but most of the cloth sent out by the manufacturers is galvanized. This is not done however to increase its efficiency in the concrete but to protect it from climatic conditions prevalent before the material is laid.

"An important feature of the Clinton system is its flexibility whereby it may be adapted to meet many requirements. Another point to its credit is the evenness of

mesh, causing uniformity of strength throughout.

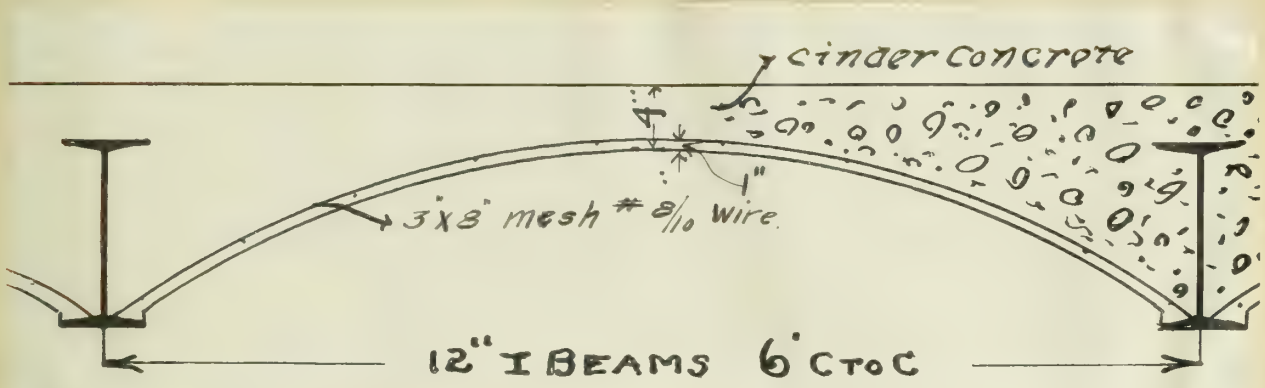


Fig. 14.

The floor construction is shown in figure 14. This is the class of floor recommended by the "Bureau of Buildings" of the City for use there. The safe load is 250 pounds per square foot. The factor of safety is five.

Several tests have been made by Dr. H. Higson of the Mechanical Engineering Department of Columbia University. One slab of this floor was first heated to an average temperature of 1700°F. for four hours and then suddenly subjected on the underside to a 1" inch stream of cold water under 60 pounds pressure. After the first one minute the water was nearly all gone, and

The concrete construction [illegible]
[illegible] of the reinforcing [illegible]
[illegible].

Among the many buildings in which the Clinton system was used are the "Maine Monument (Spanish), Columbus, and the "Stock Exchange Trust Building," New York.

Bibliography.—

"Architects' and Builders' Edition" - [illegible]; Clinton Fire-Proofing System - Clinton Steel Co. Clinton, Mass.

4.- American System

The American System consists of [illegible] with plain round [illegible] bars, both [illegible] of high carbon steel. The use of high carbon steel is based on the argument that the efficiency of a reinforcing member is dependent upon its tensile strength and high carbon steel has a greater tensile strength than other kinds of steel. The manufacturers of the following [illegible]

"ots of Reinforced Concrete," ...ere substantiating their argument." So far as ...t of a beam is concerned, ...steel ... a high elastic limit is ...desirable." "Reinforcement as high as ½ per cent for steel of ...5000 pounds per square inch elastic limit ... 1 per cent for steel of 55000 pounds per square inch elastic limit ... be used without disregarding the full compressive strength of the concrete." The ... American ... an elastic limit of 60,000 pounds per square inch and the No. 9 ... elastic ... elastic limit of 100,000 pounds per square inch. The standard types are 1, 2, 3, 4, 5, 6, 7, 8, 9, ... with ... wire ... to form 6"x6", 4"x4" or 4"x6" meshes. They are ... feet in a roll of fabric. The standard widths being 3, 4, and 5 feet.

The following is a table of tests ... were used in the ... and by Prof. Talbot, U. of I.

Tests by Prof. Talbot, U. of I.

	Area sq. ins.	Ult. Str. - lbs	E.L. - lbs/sq.in.
Av. of 2 tests on No. 9 Wire	.017	176,000	114,000
" " " " " " 11 "	.030	140,000	118,000

(Among the many advantages claimed for the American System are:

1. Ideal distribution of metal, thereby taking advantage of the full compressive strength of the concrete. [illegible] by Sir B. Baker, June 12, 1906 the following: "An instance in point is a floor of 20 feet span which was strong enough when only 3 weeks old, though it had no web reinforcing which added more than 5 per cent to the cost of the beams."

2. Continuous bond. The reinforcing rods of joists are connected by stirrups, as shown in figure 15.

3. Cheapness. The high efficiency due to high elastic limit reduces the amount of material required.

The results of a test on an "American" floor made by the N.Y. Building Department are given [illegible] the span of the floor was 17 feet and spaced 5ft. 6 in. center to center.

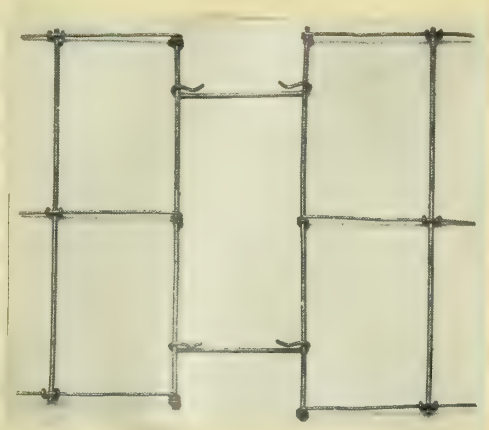


Fig. 15 — Am. Hy.

ours heated to 1700°F. for 4 hours, [illegible] which, at 1/8 inch fire stream under 60 pounds pressure played in [illegible] bot[illegible] third bottom.

Test Table.

Load-lbs/□'	Deflections - inches		
	East	Centre	West
150	0.10	0.025	0.125
300	0.175	0.050	0.10
450	0.175	0.075	0.175
600	0.20	0.125	0.175
600	0.175	0.200	0.175
450	0.125	0.175	0.20
300	0.150	0.10	0.175
150	0.075	0.125	0.150
0	0	0.10	0.125

The following recommendation was made by Mr. Ewing Engineer of the tests: "In consequence of the good record made by the floor during the various investigations, the various conditions of section 26 of the By-law having been complied with, I would respectfully recommend that the structure be relaid up to spans of 5 feet C.-C. with the usual allowable [illegible]

of 6 different constructions tested."

The specimen of the American system is to be seen in the Builder's Exchange Building at Minneapolis, Minnesota, which [illegible] is open to public view.

Bibliography.

"The Test of Two Steel Forms of Bar for Concrete", by M. O. Eddy, Asst. Engr. Mass. Inst. Tech.; American Society of Reinforcing for Concrete Construction, Chicago Ill."

5. Lock Woven-Wire Fabric

This form of reinforcement was recently used in the [illegible] Minnesota in other [illegible] reinforcements. The fabric is put up in rolls 5 inches wide and 150 feet long. The ultimate strength of the reinforcement varies about 16,000 pounds per square inch. The material is manufactured by the [illegible] Co. of [illegible]. It is very [illegible] reinforcement [illegible] [illegible] [illegible]

the Lawrence Manufacturing Co's wire tie, at each connection, which is intended to make a good joint. [illegible] of tests on a Lock Joint Iron Pipe Flange is given in the Engineering News for May 9, 1901. [illegible] the same [illegible] [illegible] of it and for the Lawrence [illegible]

III. EXPANDED METAL.

The Expanded Metal system is sometimes considered as a mat system - but although it is [illegible] under a form of matting, the account of its general make-up being together [illegible] from those commonly classified as matting, we will [illegible] it in a class by itself.

Expanded Metal is made from sheet steel cut with the grain and stretched into diamond-shaped meshes, the finished product being from 3 to 12 times as wide as the sheet steel. The material varies in thickness from No. 20 gauge (.017 inches) to No. 4 gauge (.23 inches) and the [illegible]

Fig. 16

are given very satisfactory. In it we accredited the advantages of great strength, ductility, &c. Secured by the proper and judicious use of manganese. The judicious use of this element is considered to be that which will produce results, when treated in connection with other elements, such as carbon, phosphorus, sulphur, silicon, &c. in the best steels. Such are those containing about 1% of manganese and 1% of carbon, hardened in water, and a little more elaborate than plain steel.

There have been many tests made on this kind of construction and the results of these experiments are very satisfactory. The results for all ordinary purposes. The results and conclusions of tests are given in the "Journal of the Association of Engineering Societies" for February, 1901.

Results of Tests.

No. of Test	Length of Span	Thickness, inches	Nature of Concrete: Cement	Sand	Gravel	Age-days	Distributed Load #/ft	Deflection-inches	Size of Metal.
1	1'-1"	3"	1	2	3	30	[illegible]	0	5" mesh #10 gauge
2	4'-1½"	3"	1	2	3	31	[illegible]	0	"
3	5'-2"	3½"	1	3	6	30	[illegible]	1/16	"
4	4"-0	3½"	1	2½	5	30	750	0	"
5	6'-0"	3½"	1	2	5 Rock	30	1400	1/4	"
6	6'-0"	4"	1	3	6	28	850	1/16	"
7	[illegible]-4"	4"	1	3	6	30	914	5/16	"
8	5'-4"	6"	1	3	6	30	914	0	"
* 9	11'-0"	6"	1	2	5	30	360	9/64	2 sheets 3"-#10 gauge
10	4'-0"	2½"	1			30	76	Broke	No Metal
11	4'-0"	2½"	1			30	356	Broke	3" Mesh #10 gauge

The cement used was [illegible] Portland.

* - When load was removed 3/64 inches deflection remained.

Among the examples of Expanded Metal reinforcement in the Office of [illegible] and Consulting Engineer Chicago containing [illegible] sq. ft. of Expanded Metal [illegible] 19[illegible].

CONCLUSION

develope its full compressive strength. For any particular construction the way in which the concrete is to be reinforced is a matter of judgment derived from experiment, common sense and experience.

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